# Energy Efficient High-tech Buildings

Can anything be done to improve Data Center and Cleanroom energy efficiency?

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# Acknowledgements


- California Energy Commission
- Pacific Gas and Electric Company
- Federal Energy Management Program (FEMP)
- 7 x 24 Exchange
- Uptime Institute
- Rocky Mountain Institute
- NYSERDA
- E Source
- Rumsey Engineers
- EYP Mission Critical Facilities
- Industry Partners (Too many to name all)

# Data Center efficiency

- Benchmarking
- Case study example
- Power conversions
- Selected opportunities for improvement

# We also operate data centers –

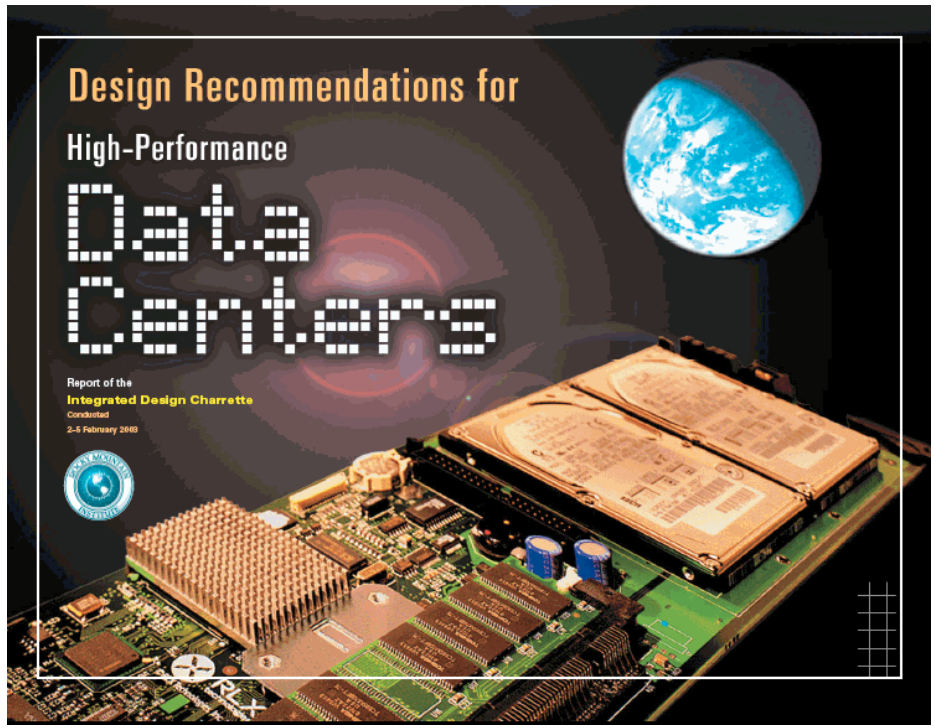
## National Energy Research Scientific Computing supercomputer center in Oakland

# California energy research related to data centers

- Energy research roadmap
- Case studies and energy benchmarking
- Best practice identification
- Self benchmarking protocol
- Investigate efficiency of power supplies in IT equipment
- Investigate efficiency of UPS systems
- Metrics for computing performance vs. energy
- Technology transfer
- Demonstration projects

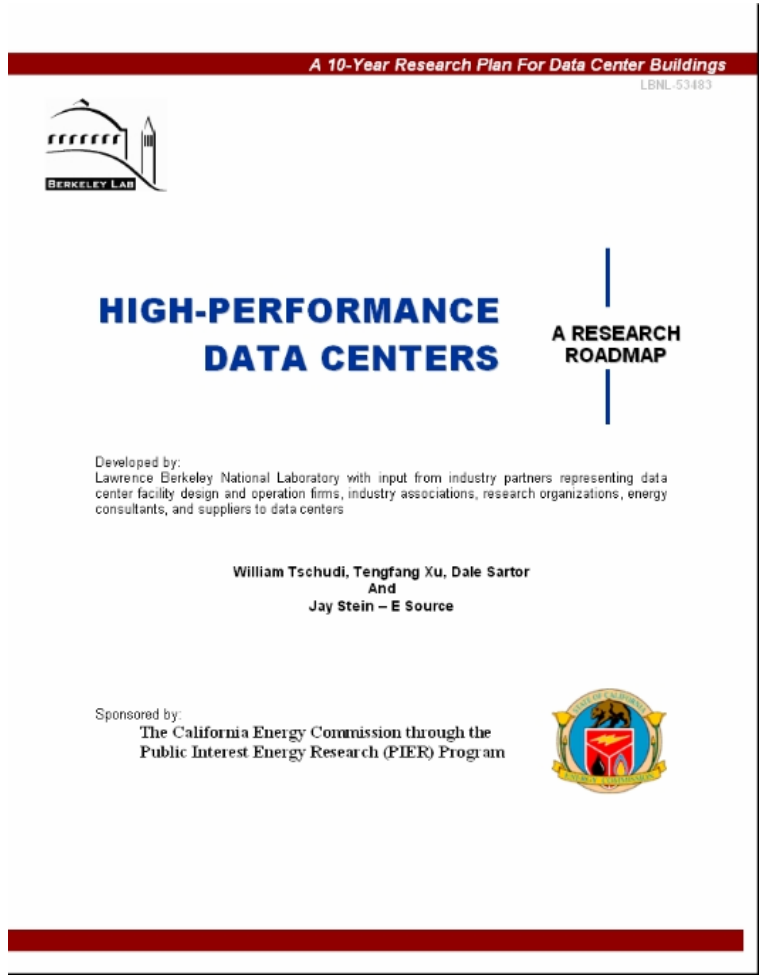
# Data center efficiency opportunity

- Industry professionals, LBNL and others brainstormed efficiency improvements at RMI Charrette (2003)
- Practical (near term) solutions as well as longer term concepts were identified
- Available through RMI website:
  http://www.rmi.org/store/



# Data center energy roadmap

- Input through workshops, conferences, and contacts with industry professionals.
- Participation in design charrette facilitated by the Rocky Mountain Research Institute (RMI)
- Selected research areas are being pursued
- Available through LBNL website: http://datacenters.lbl.gov/docs/RoadmapadmapFinal.pdf



# Why benchmark data centers?

- Utility load growth planning
- Baseline energy use
- System and component efficiency comparisons
- Best practices using current technology
- Identify areas where further work is required

# April 10, 2003 San Jose Mercury News

"A new power plant is up and running in San Jose's Alviso neighborhood, but the massive Internet server farm that it was supposed to fuel is nowhere in sight.

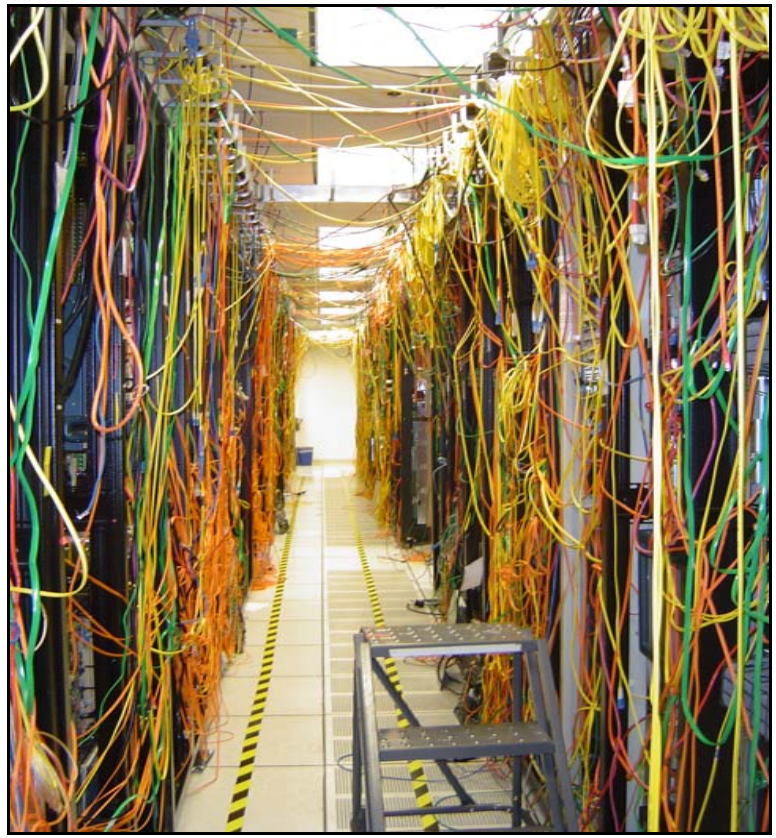
The Los Esteros Critical Energy Facility, a 180-megawatt plant built by Calpine in North San Jose, was designed to power an adjacent Internet server farm by U.S. Dataport. The server farm never broke ground -- and company officials didn't return calls Wednesday to say if or when it might -- but Calpine proceeded with the plant anyway, after securing a three-year deal with the state Department of Water Resources to buy power.

Company and state officials say the plant is still needed, even though the state's infamous energy crunch of 2000-01 is long over."

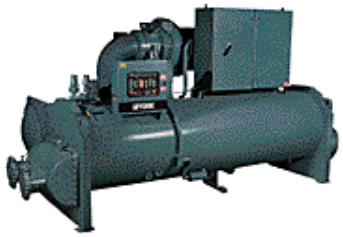
180 MW:  900,000 sq.ft. x 200 W/sq.ft

# Case studies/benchmarks

- California
  - Storage device and router Mfgs.
  - Banks
  - Web hosting facilities
  - Internet service provider
  - State tax center
  - Federal facilities
- New York
  - Recovery center (hosting)
  - Financial institution



# Electricity flow in Data Centers



HVAC system

lights, office space, etc.

uninterruptible power

local distribution lines to the building, 480 V

UPS

PDU

computer racks

computer equipment

backup diesel generators

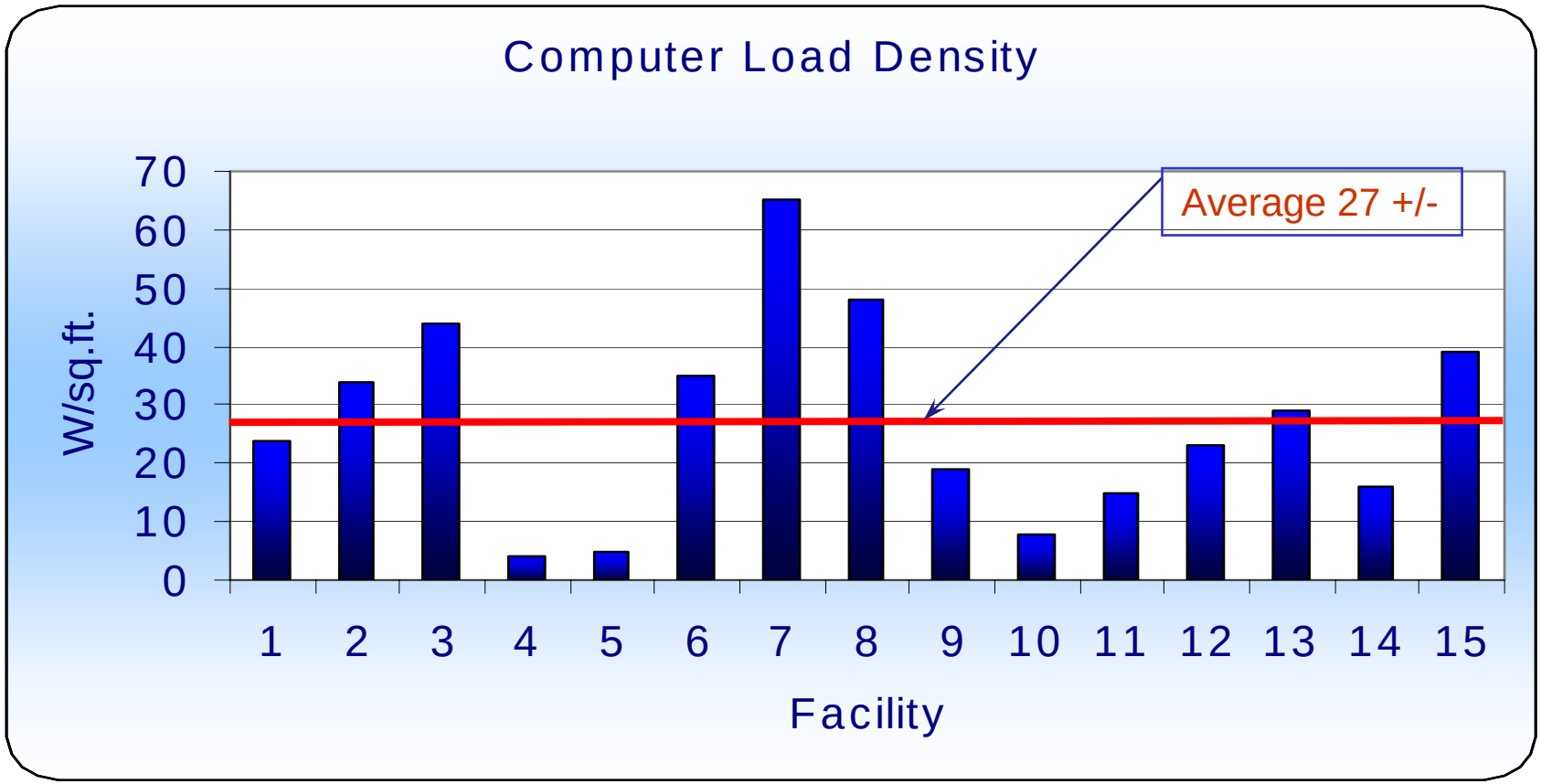
UPS = Uninterruptible Power Supply

PDU = Power Distribution Unit;

# Metrics

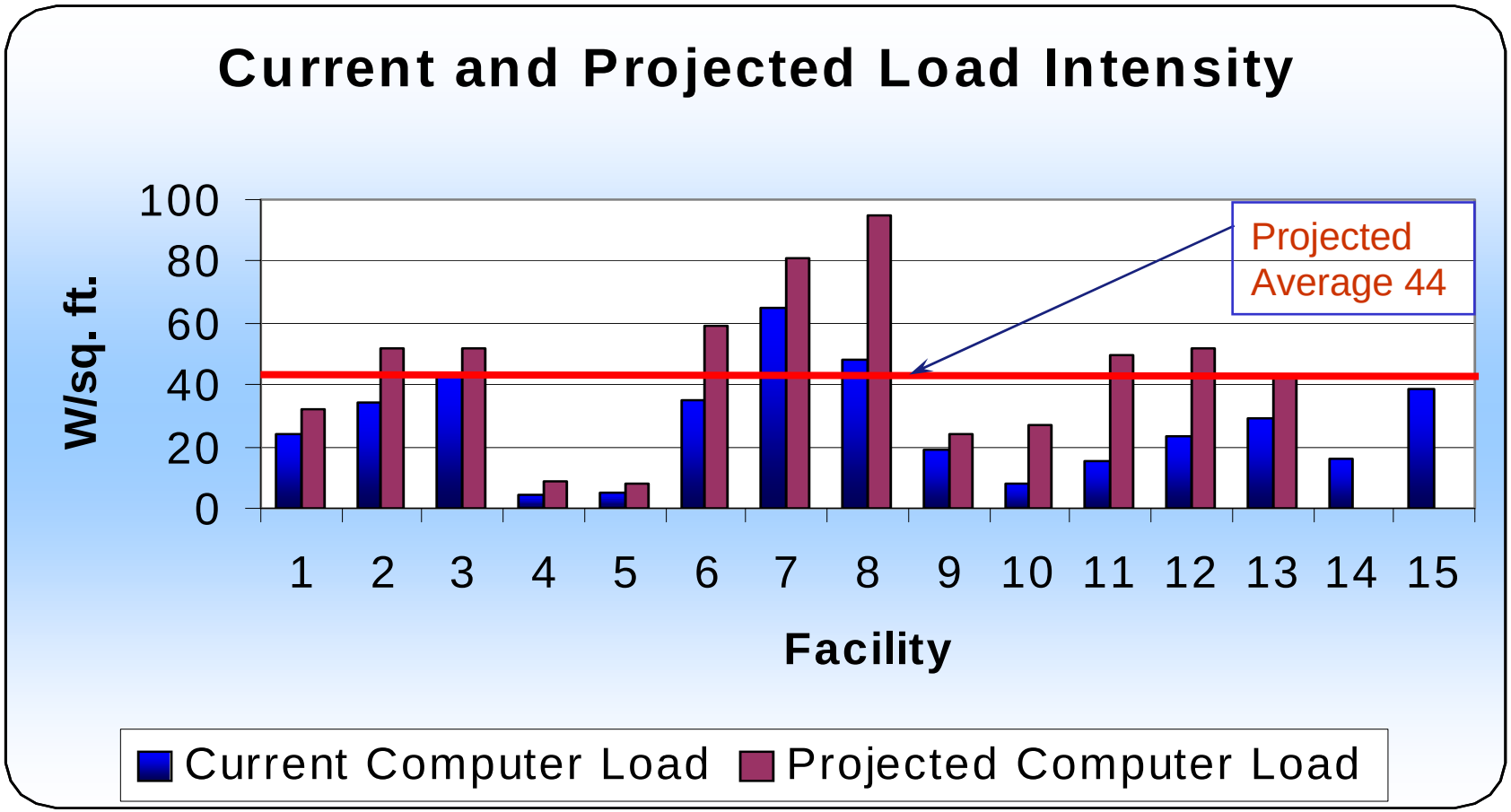
- IT equipment load intensity: W/sq. ft. (electrically active space – Uptime definition)
- UPS losses: %
- Chilled water: kW/ton; W/sq.ft.
- End use pie chart: W/end use; W/sq.ft.
- Occupancy: % full (subjective)
  % of design load
  (readout from UPS or PDU)

# 2003 IT equipment loads
## (W/Sq.Ft. of electrically active floor space)

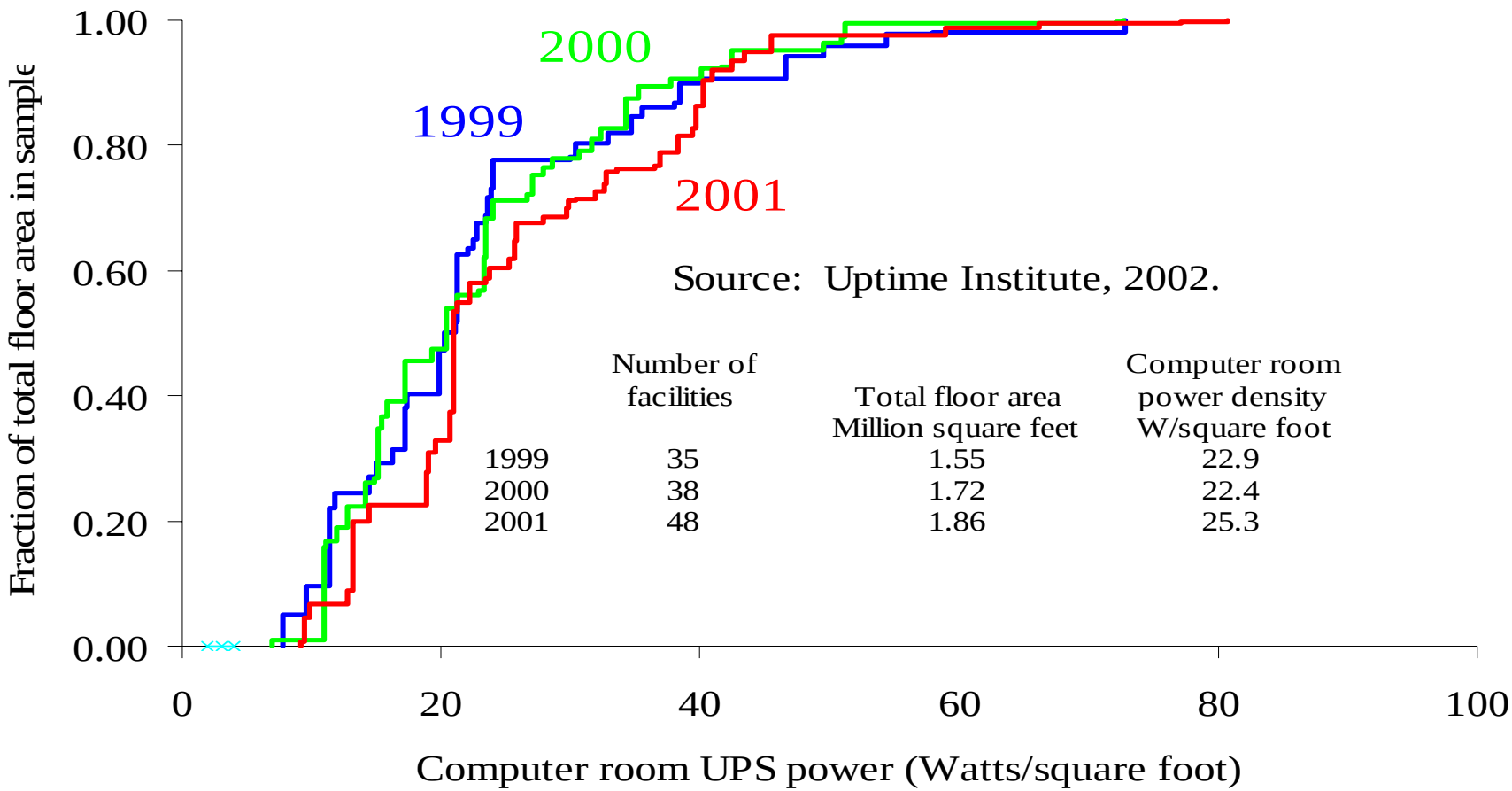


# Projecting fully loaded conditions

## (W/Sq.Ft. of electrically active floor space)

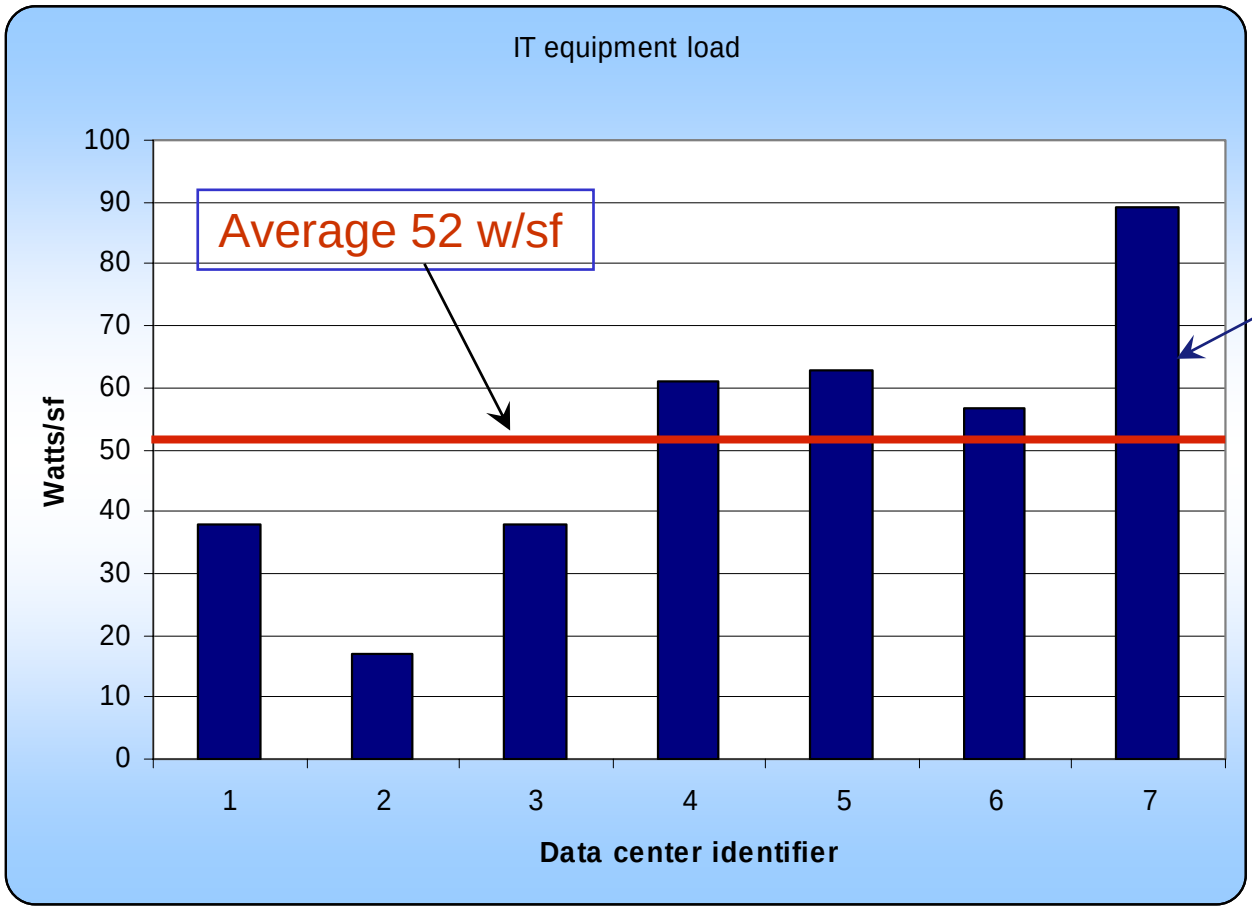


# Distribution of computer room power reported to Uptime Institute

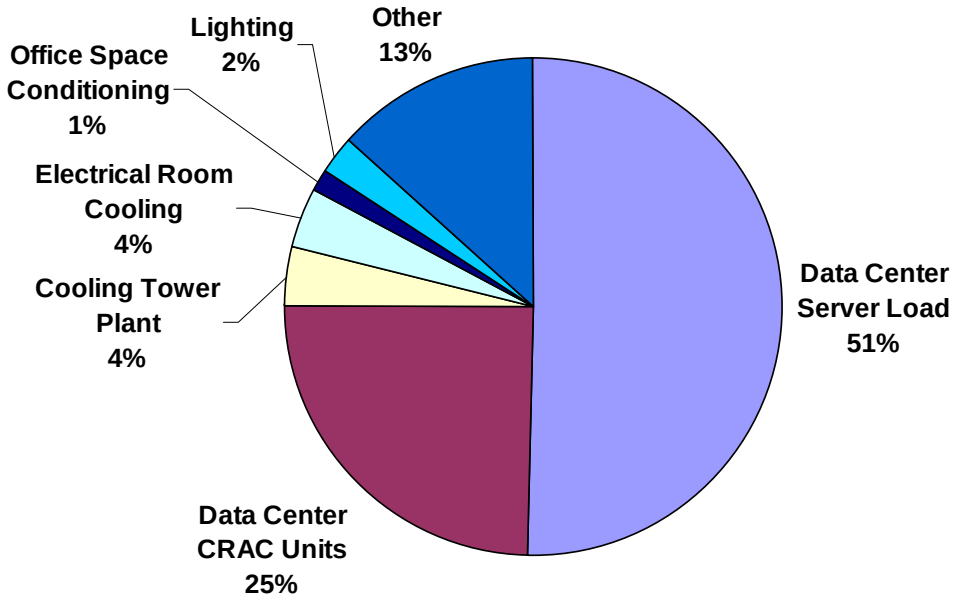


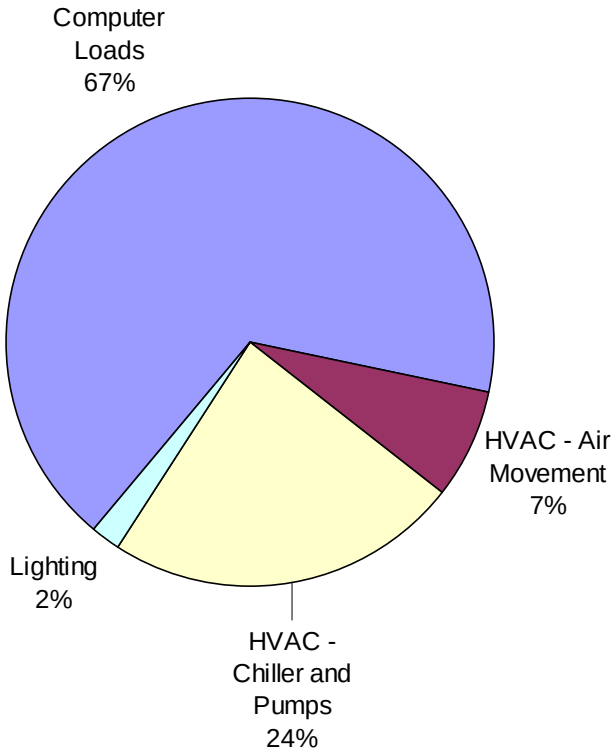

| | Number of facilities | Total floor area Million square feet | Computer room power density W/square foot |
|---|---|---|---|
| 1999 | 35 | 1.55 | 22.9 |
| 2000 | 38 | 1.72 | 22.4 |
| 2001 | 48 | 1.86 | 25.3 |

# 2005 IT equipment benchmarks

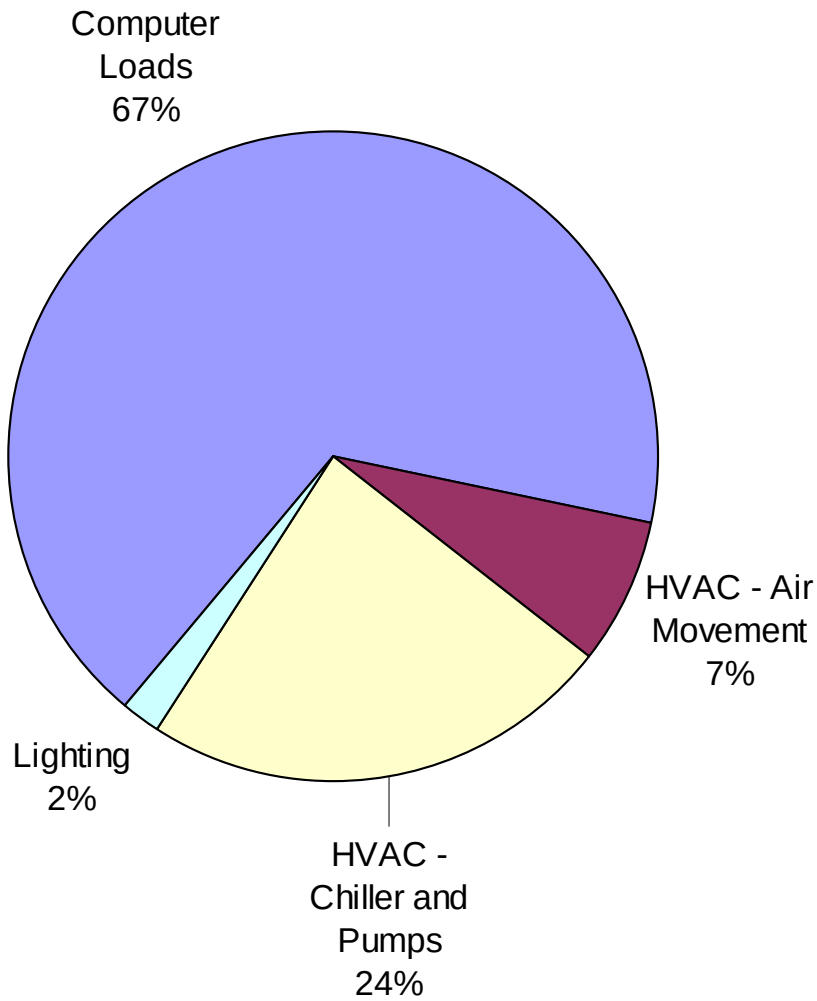


# End-use pie charts vary

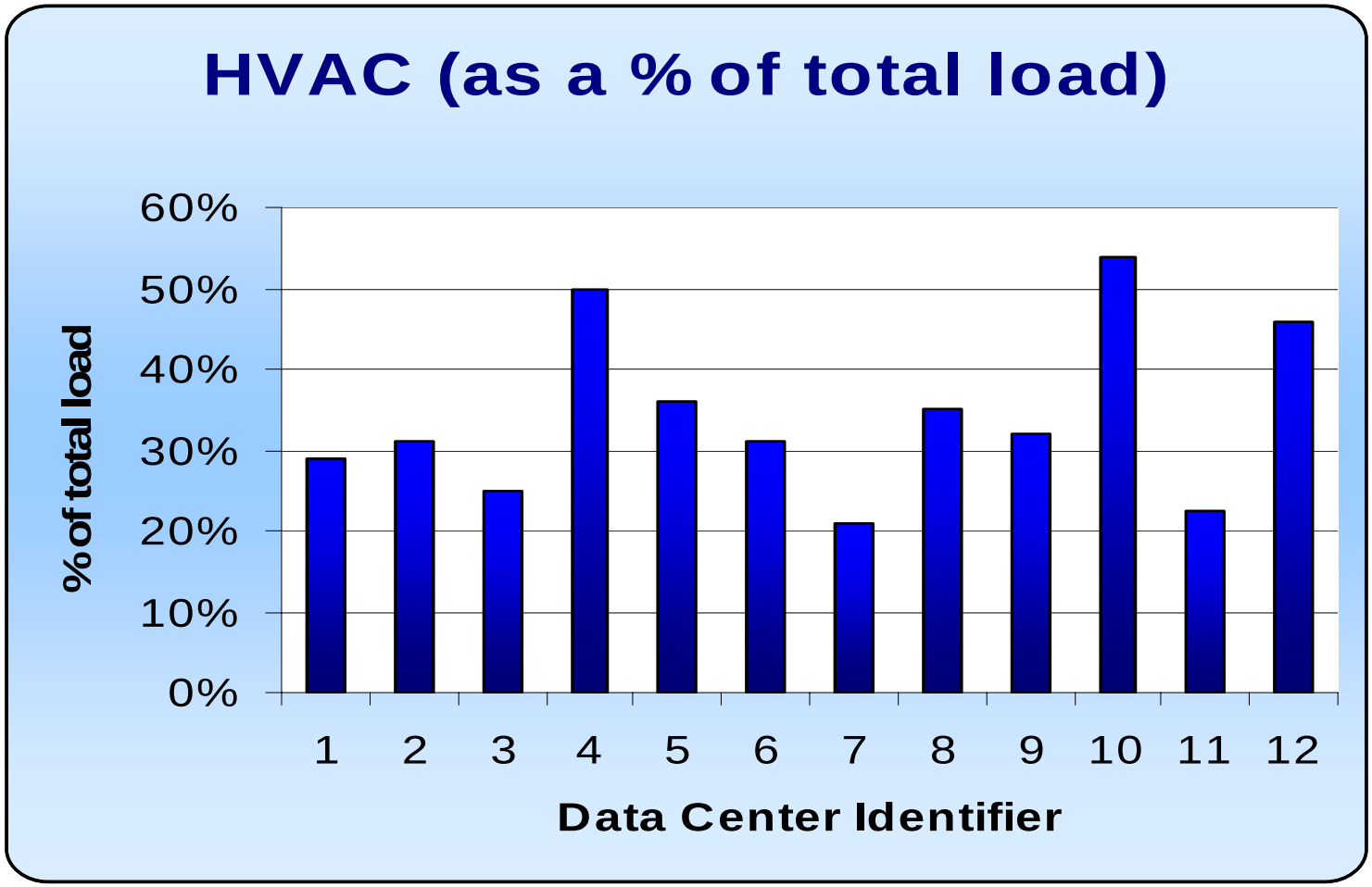


# A better ratio is when infrastructure loads account for a smaller percentage



# Effectiveness of HVAC systems



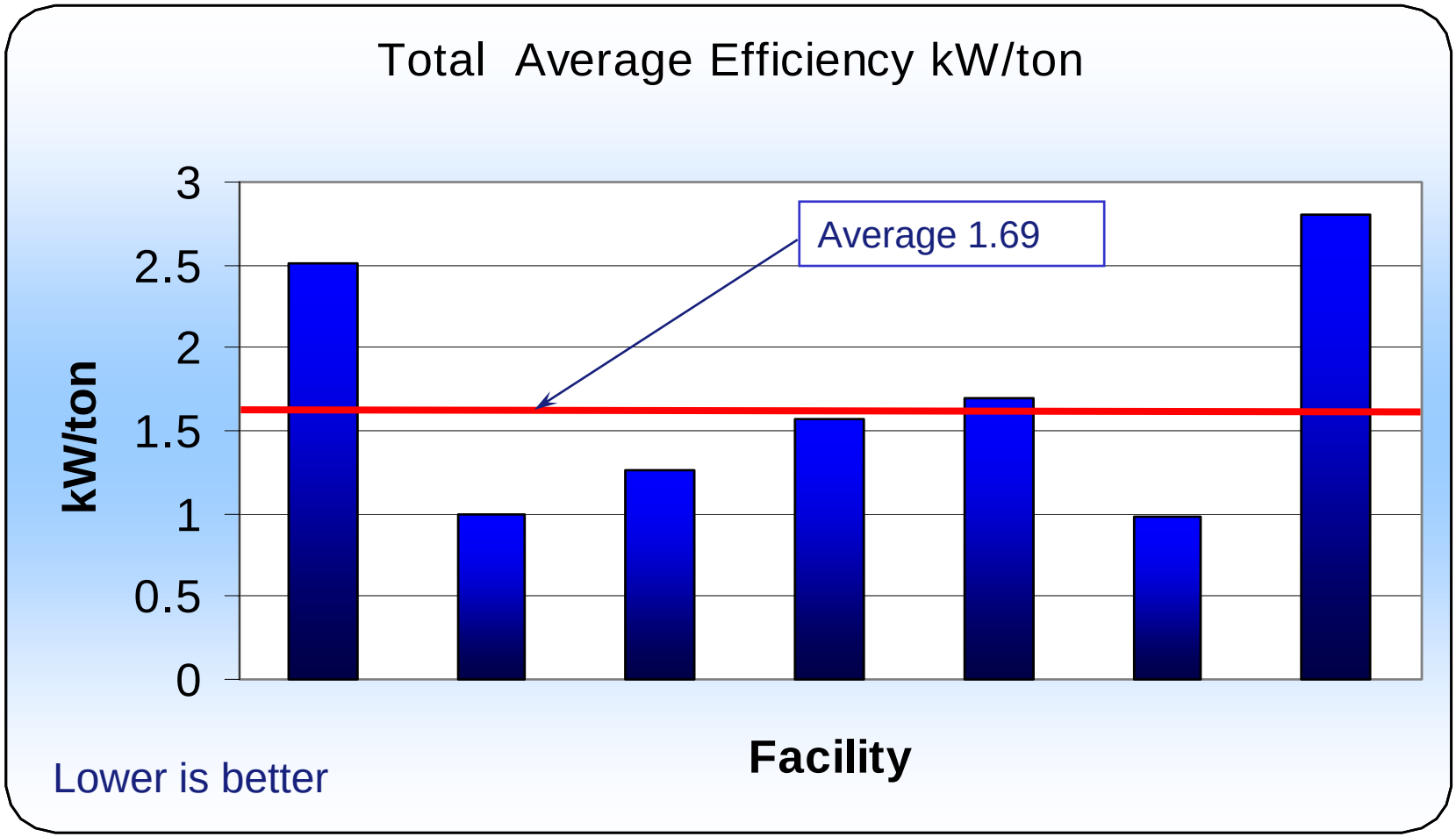
# Index of performance

The Uptime Institute proposed a metric to evaluate the total efficiency of infrastructure systems:

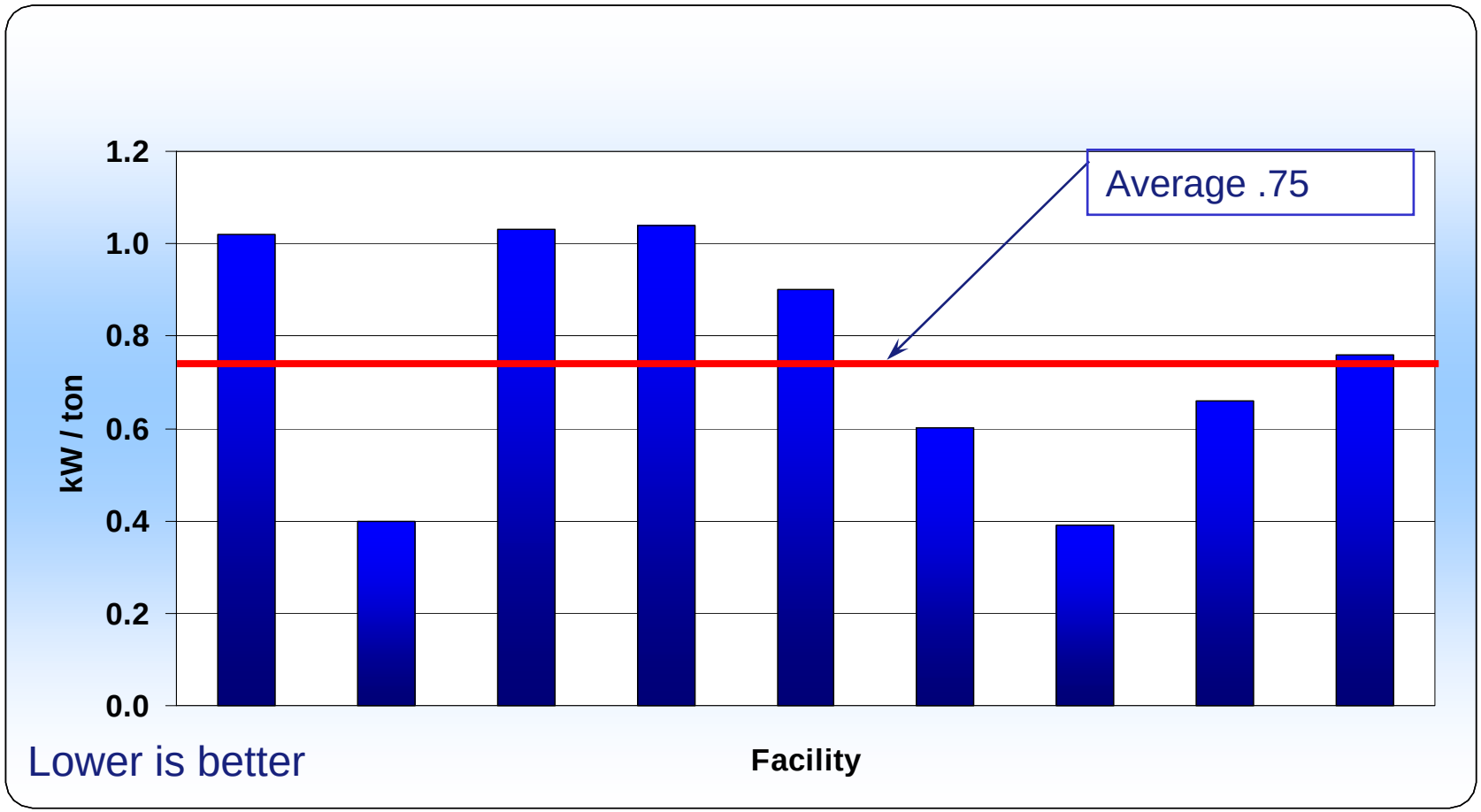
Index of performance = building systems KW ÷ UPS output

(i.e. ratio of building systems to IT equipment load)

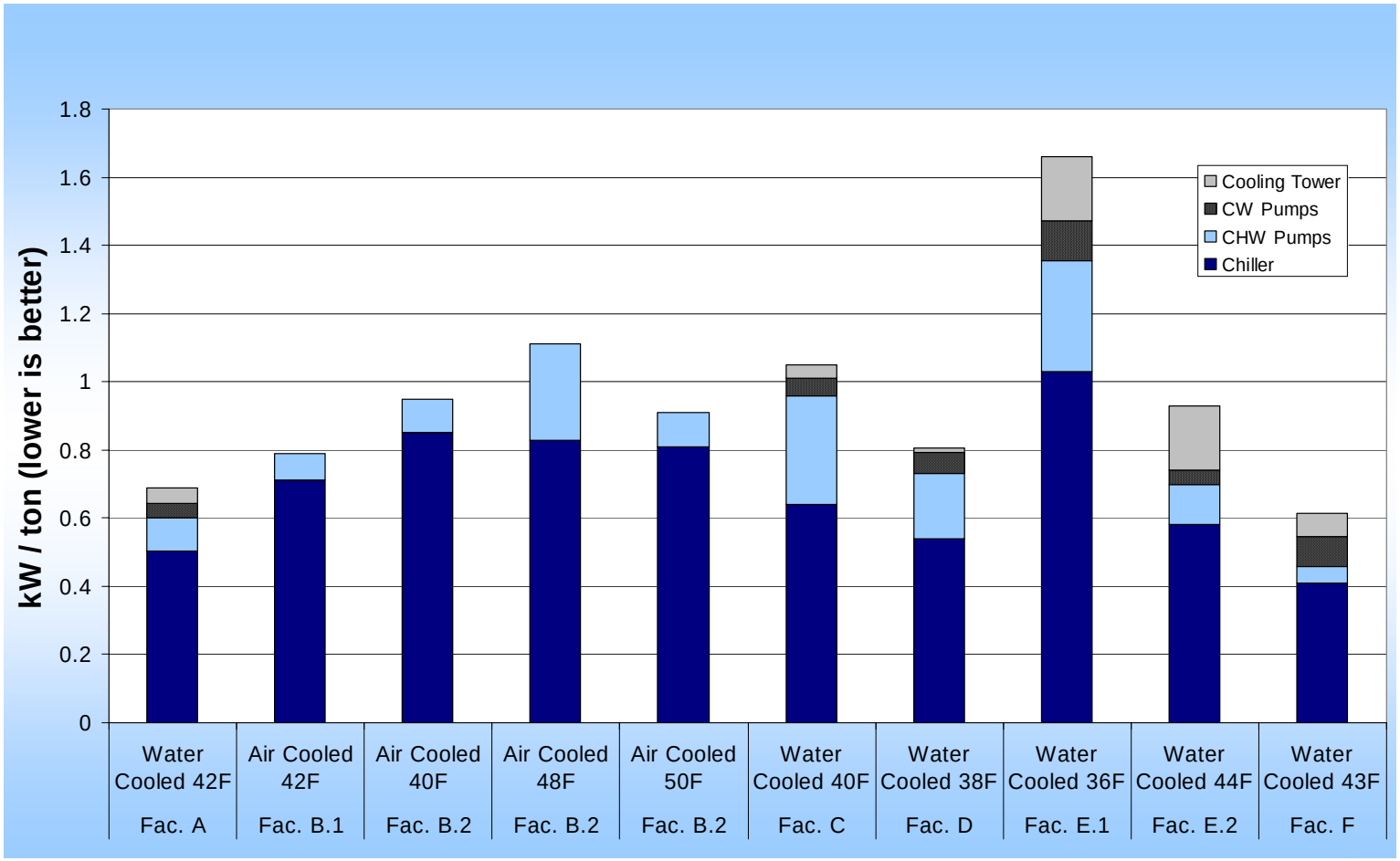
# Total chilled water system efficiency



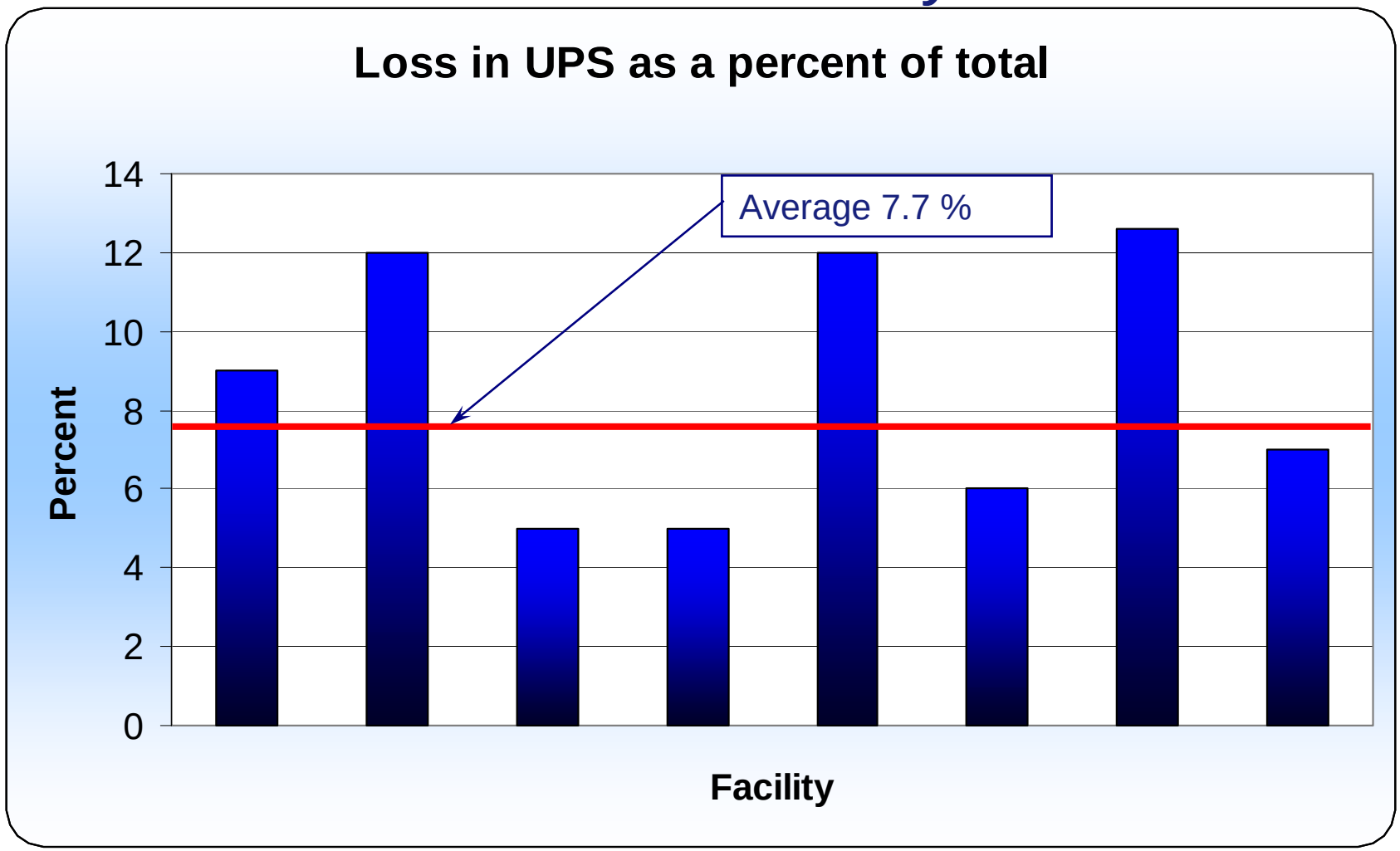
# Chiller comparison



# Chilled water systems efficiencies

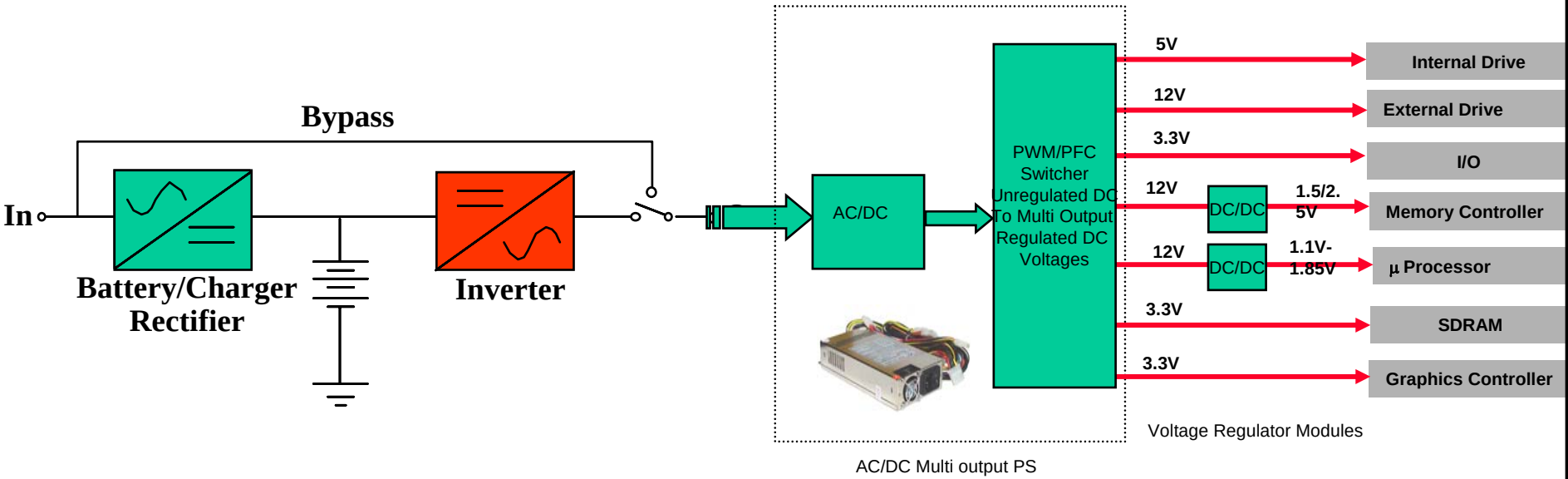


# Power loss in UPS systems

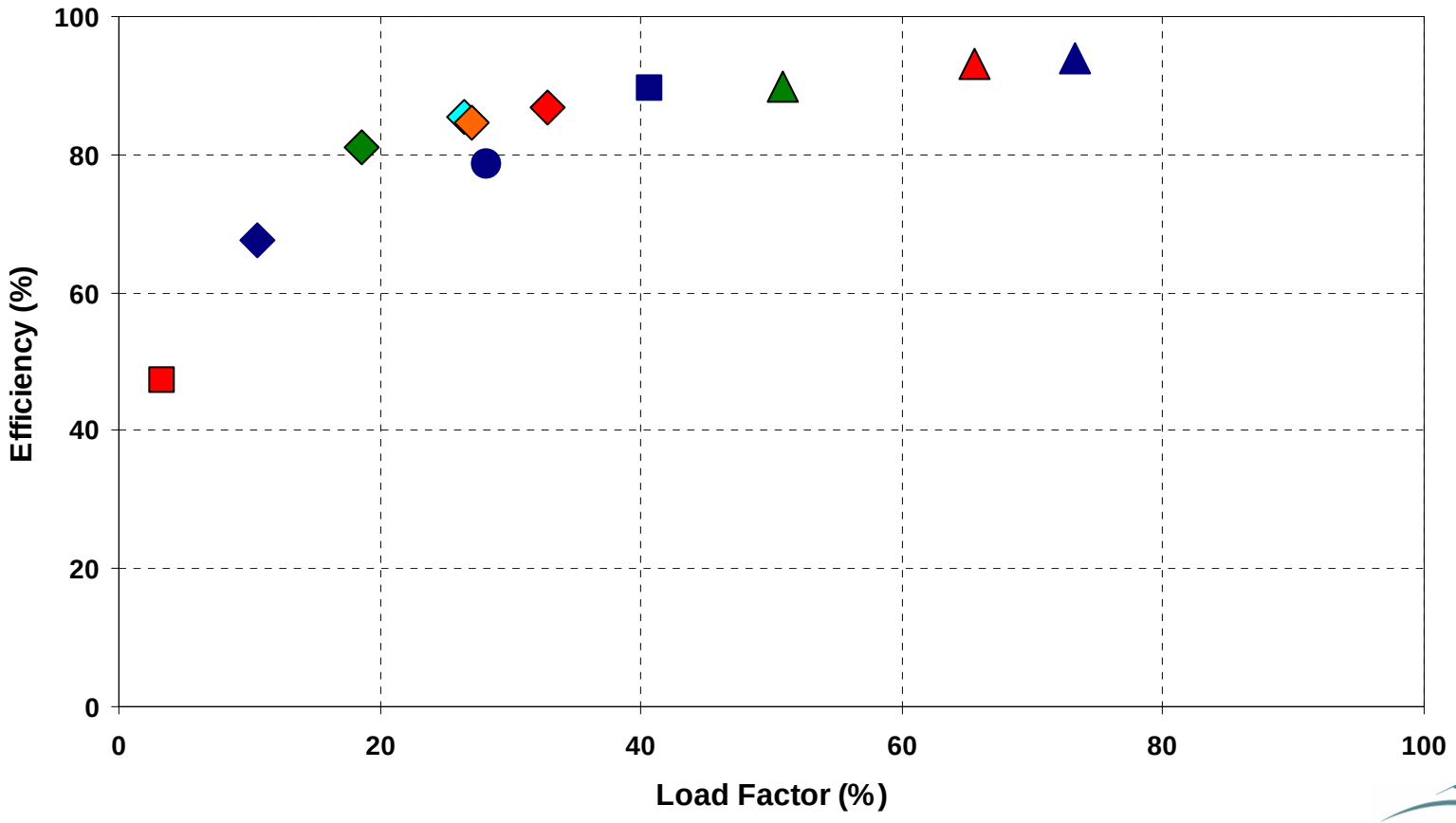



Cooling loads compound this

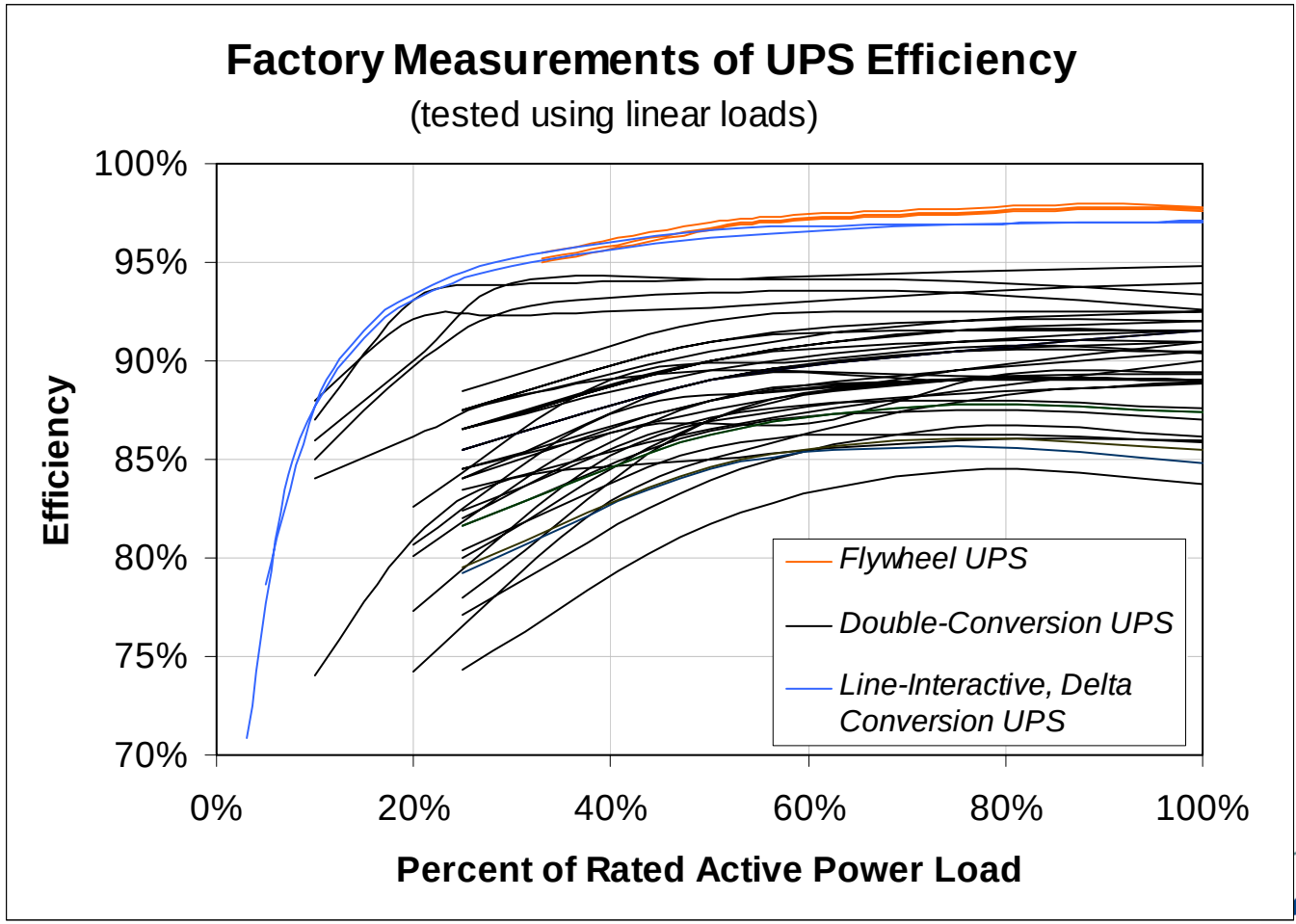
# How many times do data centers convert AC and DC?



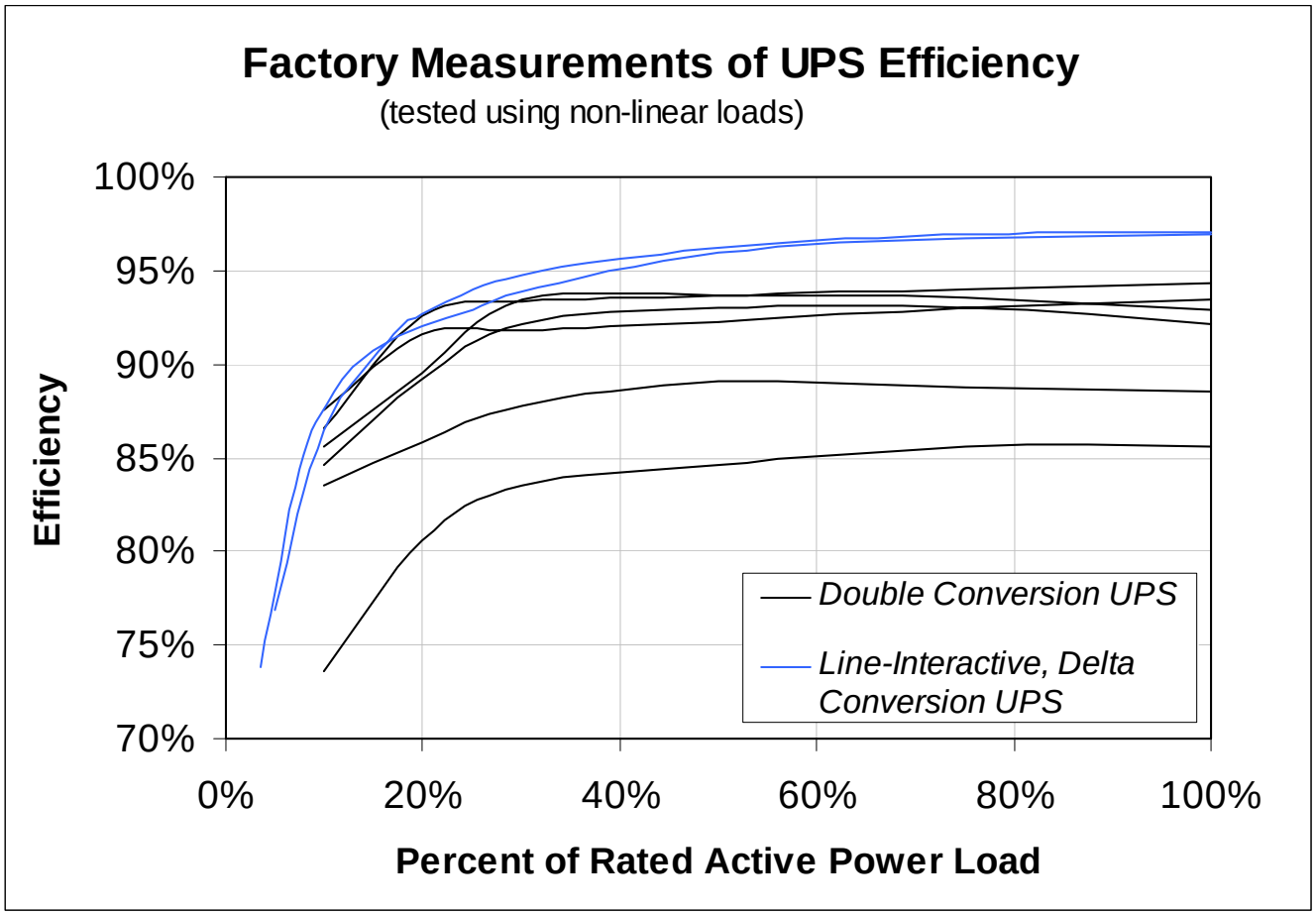
# Measured UPS efficiency



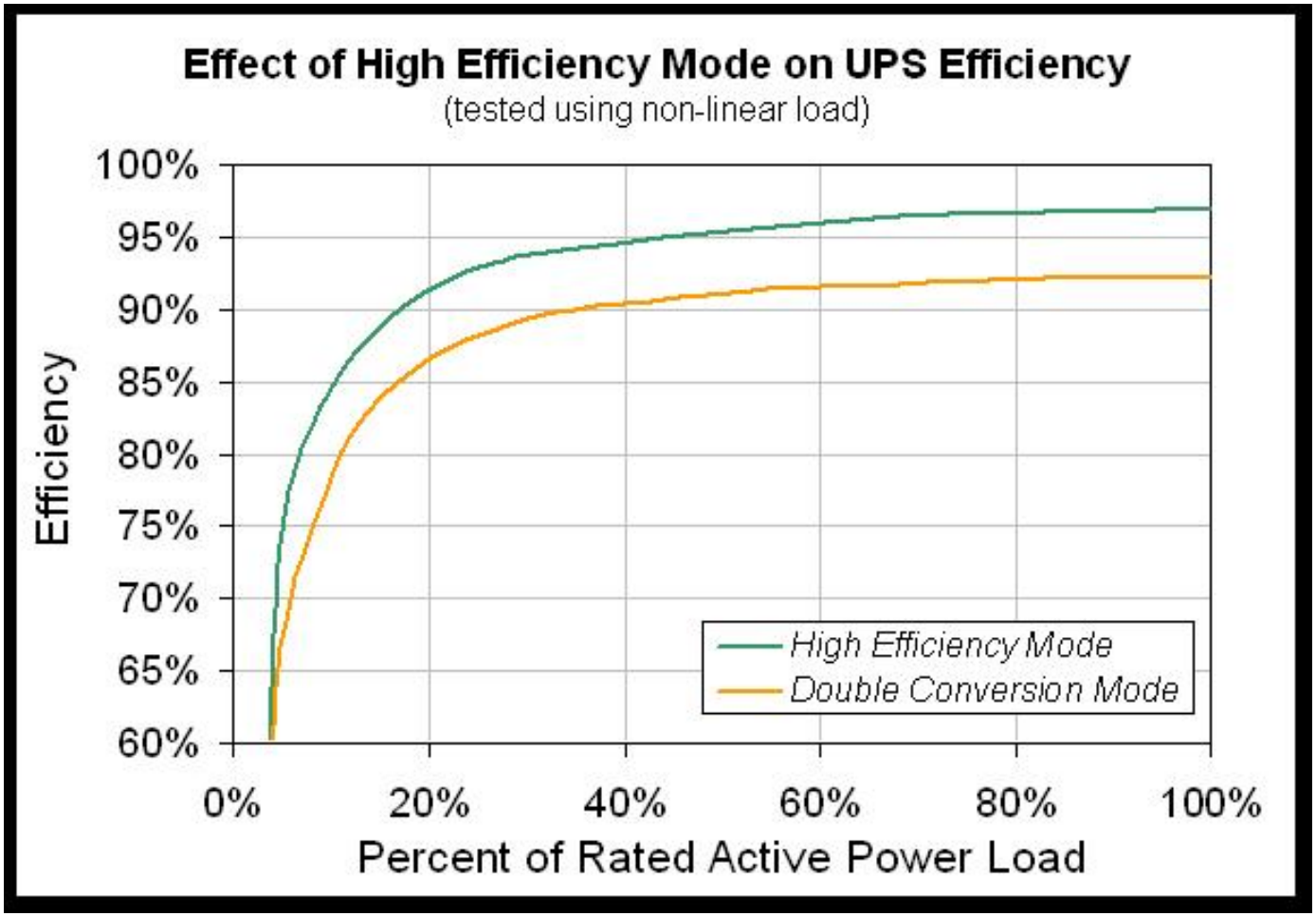
# UPS factory measurements



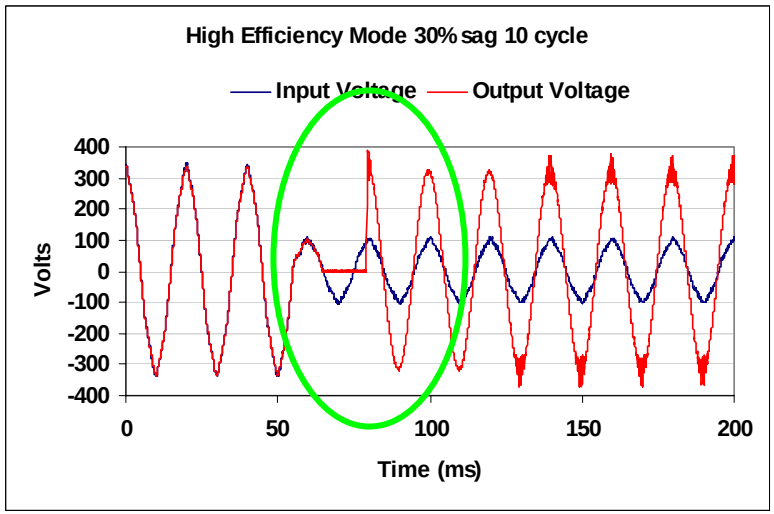
# Measured UPS losses

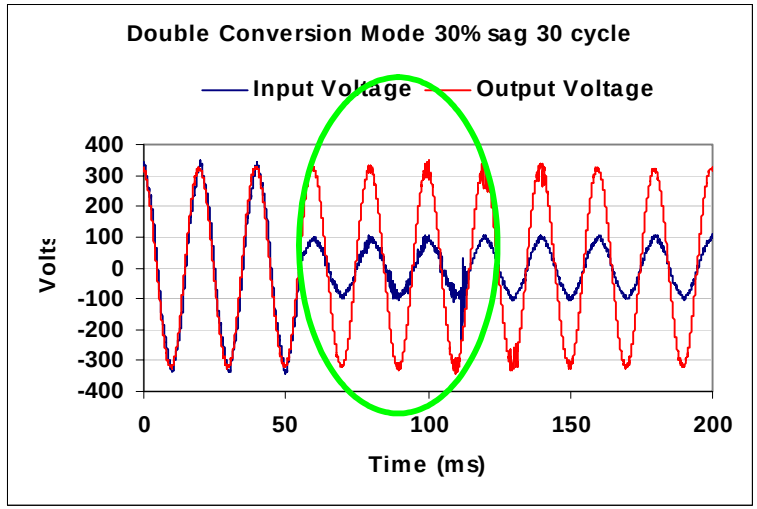


# Double conversion UPS systems can be more efficient today



# Analyzing UPS performance in "high efficiency" option



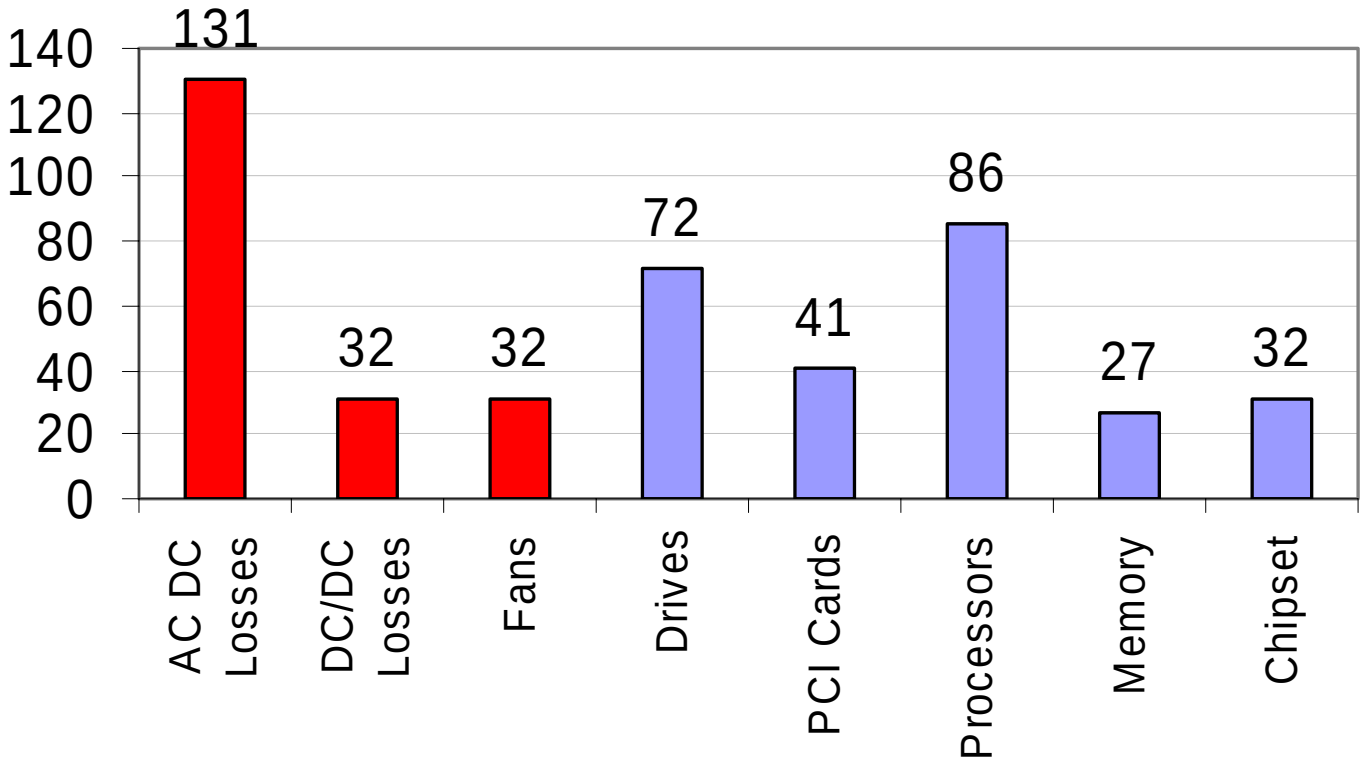




Source: EPRI Solutions

In "high efficiency" mode, there is typically one cycle (16.6 msec for 60 Hz) of UPS output voltage deviation.

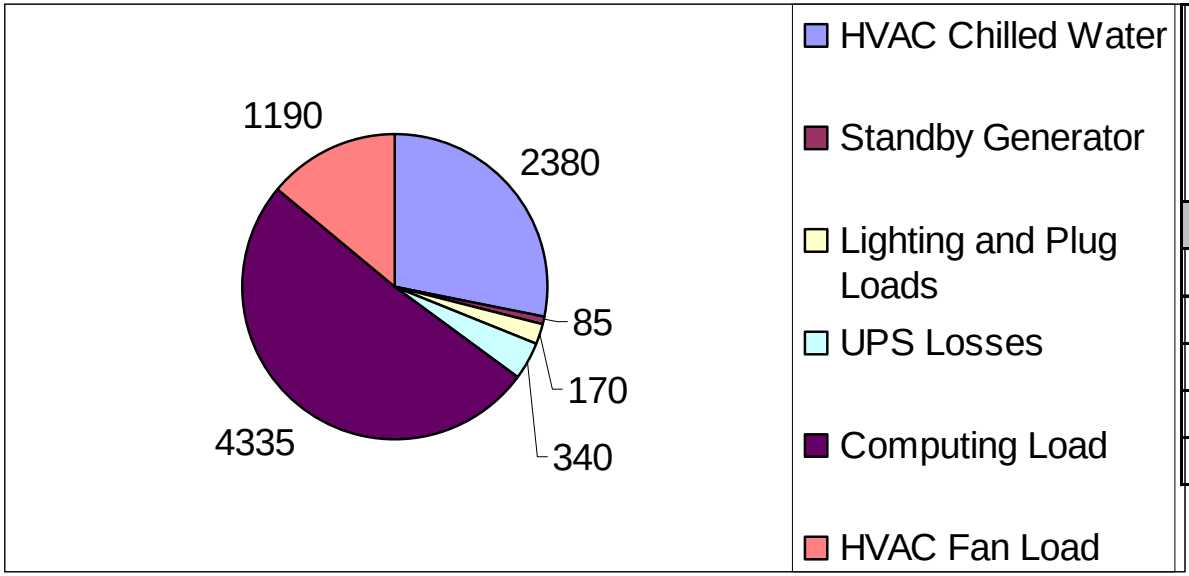
***Power supplies downstream of UPS can ride through this!***

# Electricity use in a server




**Based on a typical dual processor 450W 2U Server; Approximately 160W out of 450W (35%) are losses in the power conversion process (Source: Brian Griffith: INTEL)**

# Power supply opportunity

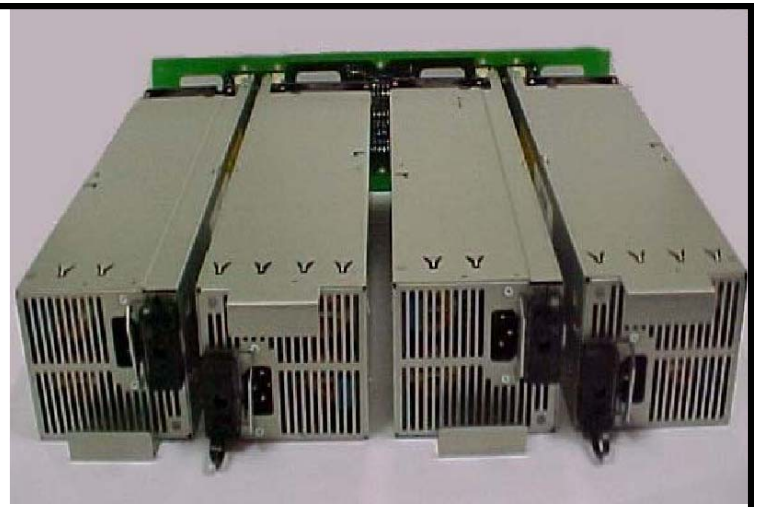



| Efficiency of Power Conversion Process | IT Load (kW) | UPS Losses (kW) | Total Savings (kW) |
|---|---|---|---|
| 65% | 4335 | 340 | 0 |
| 70% | 4025 | 316 | 334 |
| 75% | 3757 | 295 | 623 |
| 80% | 3522 | 276 | 877 |
| 85% | 3315 | 260 | 1100 |
| 90% | 3131 | 246 | 1299 |

Based on one case study approximately 4335 KW of a total of 8500 kW was IT load. Assuming a 65% existing baseline efficiency, the savings opportunity using 90% efficient conversion process is approximately 1300kW not including any savings from HVAC

# Power supply efficiency today

Full Load Efficiency > 68%



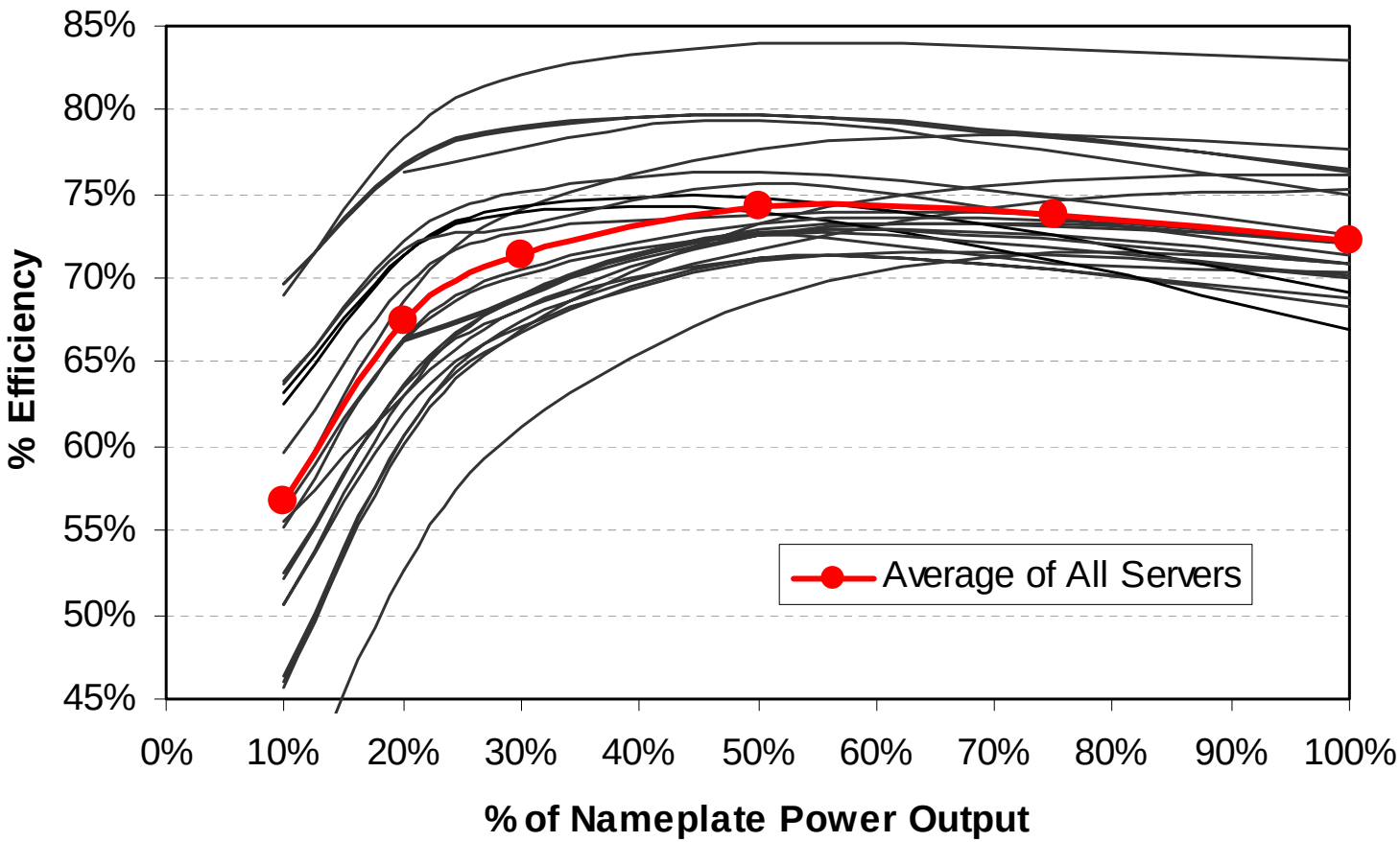
Redundant System of Power Supplies for Servers

## Electrical Specifi ons

### Input

| | |
|---|---|
| Input Range | 90-264 VAC (Wide Ranging active pfc ) |
| Frequency | 47-63 Hz |
| Input Current | 6.3A @ 100VAC; 3A @ 200VAC |
| Peak Inrush Current | < 25A peak ,specified line and temperature |
| Turn-on delay | 1.5 Seconds maximum from ac applied |
| Efficiency | >68% @ Full load, specifiedl line |
| EPA | >40%@+5V/2.6A,3.4V/1A,5Vaux/0.5A, 115/230Vac |
| Blauer Engel | <8W standby input for $5V_{SB}$@500mA, 230Vac |
| EMI/RFI | CISPR 22 class B,FCC 47CFR part 15 class B, EN 55 022 class B, CE compliant. EN61000-3-2 class D ,JEIDA 75W to full load Active PFC >0.90PF |

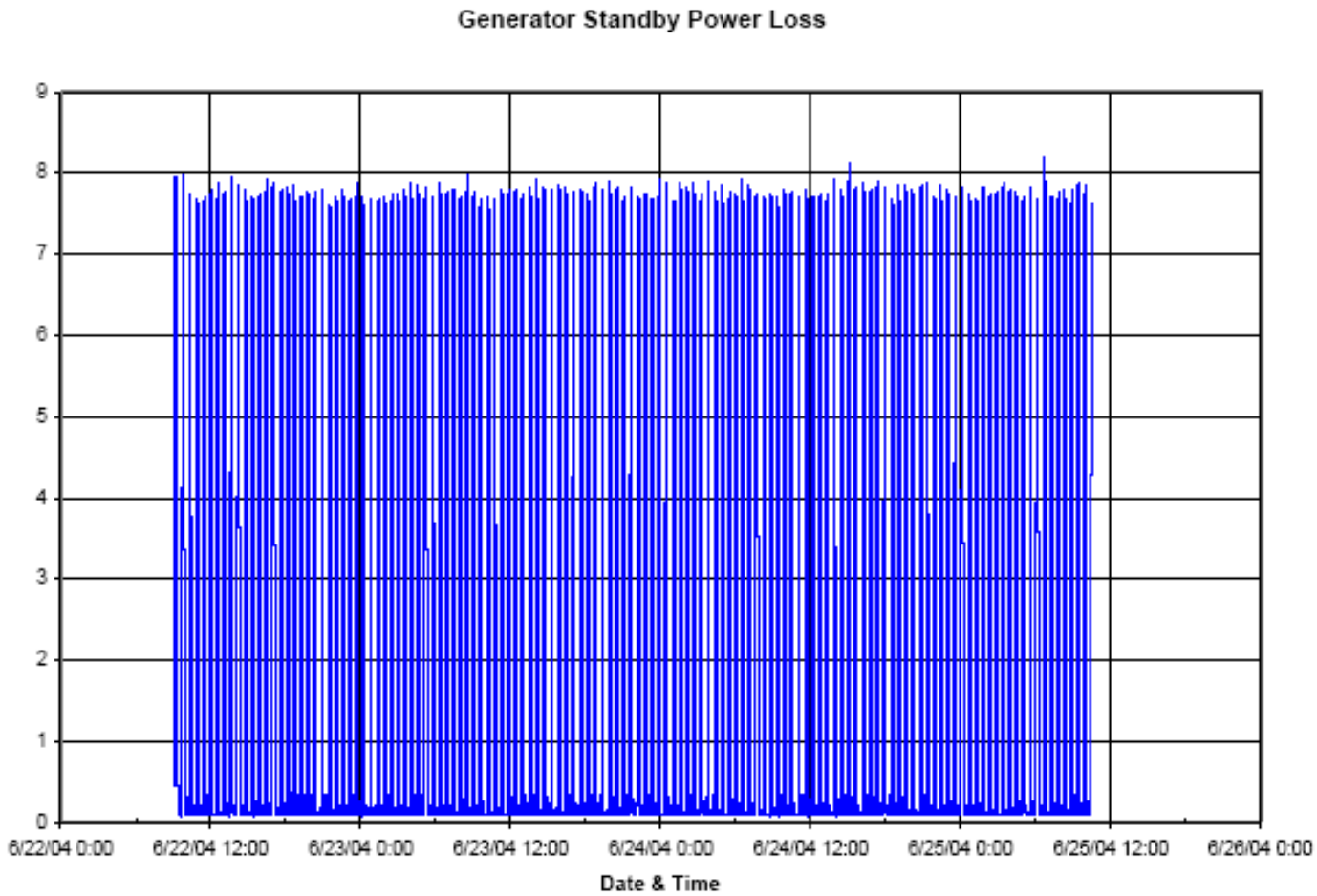
# Measured power supply efficiency



# Standby generation loss

- Several load sources
  - Heaters
  - Battery chargers
  - Transfer switches
  - Fuel management systems
- Heaters (many operating hours) use more electricity than the generator will ever produce (few operating hours)
- Opportunity may be to reduce or eliminate heating, batteries, and chargers

# Standby generator heater



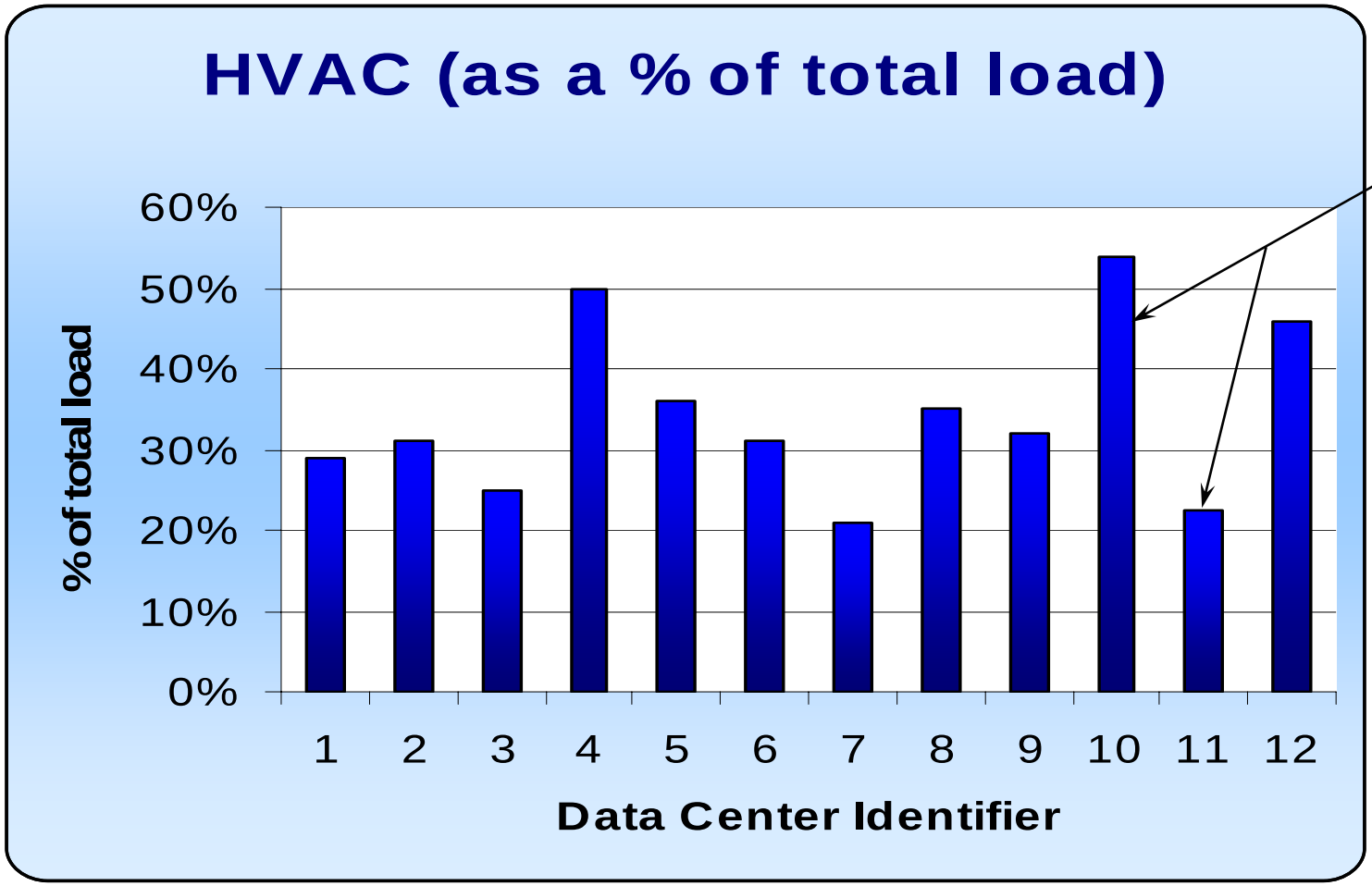
# Additional benchmarks

- Computations per Watt
- Ability to enter “sleep mode”
- Nameplate vs. Actual Comparisons
  - IT Equipment
  - UPS
  - Chillers
  - Transformers
- Others?

# California case studies

LBNL sub-contractors, Rumsey Engineers and EYP Mission Critical Facilities, performed site data collection and preliminary analysis, provided efficiency recommendations, and case studies reports.

# Case study example: Facility 8




The worst and the best ratios were both in facility 8

# Facility 8 site characteristics

## Data Center 8.1

- 26,200 sq ft
- 6 UPS's – 3 per "side"
- Redundancy: n+1 at PDU level, n+2 at UPS level
- Overhead ducted air distribution
- Air-cooled constant volume CRAC units

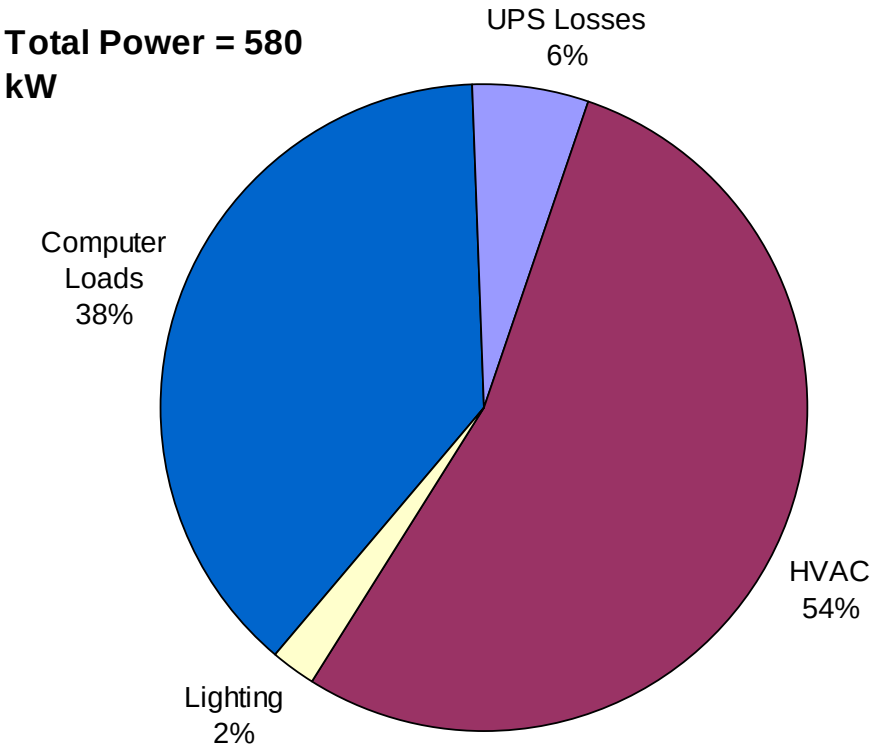
# Facility 8 site characteristics

## Data Center 8.2

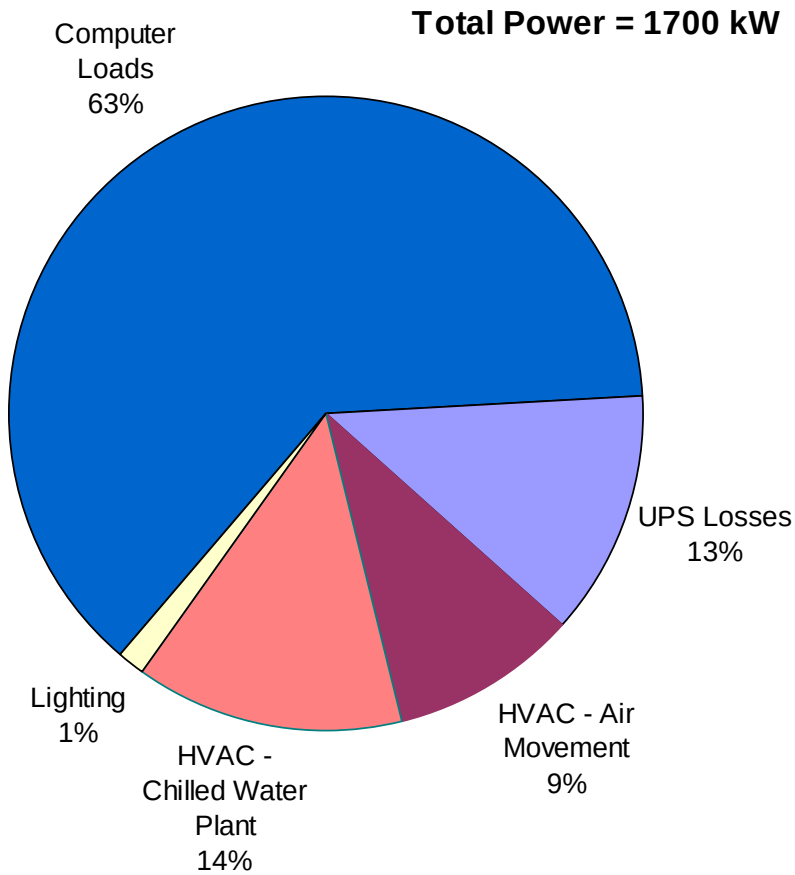
- 73,000 sq ft
- 5 UPS's
- Redundancy: n+1 at PDU level
- Overhead ducted air distribution
- Central chilled water plant
- Central air handling system
- Variable speed chiller, secondary pumps, air handlers

# Facility 8 electricity end-use

## Data Center 8.1




## Data Center 8.2



# How did they do it?

## Data Center 8.1

- Air cooled CRAC units
- No economizing
- Constant Speed Fans
- Humidification control
- All CRAC units on

## Data Center 8.2

- Optimal central chilled water plant
- Optimal central air handling units
- Little humidity control
- Good control
- Data Monitoring – Gateways, EMCS

# How could they have done even better?

## Data center 8.1 observations

- Disable humidification control
- Turn off CRAC units
- Shut off (rotate) surplus UPSs
  i.e. go from N+2 to desired N+1
- Space temperature setpoints

# How could they have done even better?

## Data center 8.2 observations

- Monitoring - chiller, total chiller plant kW/Ton
- Run Cooling towers in parallel, nozzle replacement
- Chilled water setpoint
- Condenser water temperature reset

# Energy efficiency opportunity

- "Air management"
  - hot aisle-cold aisle, bypassing/short circuiting, underfloor congestion, high ceilings and adequate underfloor areas, use of modeling
- Air and water side economizers – many hours of low cost cooling in CA
- UPS and power supply efficiencies, loading, redundancy strategies
- Temperature and humidity control
  - eliminate CRAC unit fighting, ASHRAE thermal guidelines
- Chilled water plant optimization - efficient chillers, primary only pumping, etc.
- Variable speed drives – pumps, chillers, fans
- Control strategies - setpoints, cooling tower staging
- Lighting controls

# LBNL high-tech buildings website:

http://hightech.lbl.gov

Thank you

Questions?